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THE LAST OF A BRILLIANT QUARTETTE OF PHYSIOLOGISTS—

E. DU BOIS-REYMOND

(Professor of Physiology in Berlin).

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C. Ludwig, in 1852, dedicated his "Lehrbuch der Physiologie" to his friends E. Brücke in Vienna, E. du Bois-Reymond in Berlin, and H. Helmholtz in Bonn. This brilliant quartette of Physiologists, alas! all are gone. The last survivor was du Bois-Reymond, who died at Berlin on Dec. 26th, 1896, aged 78. Du Bois, as he was often called, was born at Berlin on Nov. 7th, 1818. His family was of French-Swiss extraction, his father being a native of Neuchâtel, while his mother belonged to a French Huguenot family, which was forced to leave France during the reign of Louis XIV. Young du Bois attended the French College at Berlin, but, on his father removing to Neuchâtel, he became a scholar there. Returning to Berlin when eighteen years of age, he joined the Philosophical Faculty, but he never "inscribed himself" in the Faculty of Theology, as has been alleged, although he attended some lectures under Neander, the famous Professor of Theology in Berlin, at that time. It is interesting to recall the fact that Boerhaave, Cuvier, and J. Müller all of them started with the study of Theology. In fact, J. Müller, the shoemaker's son of Coblenz, seemed to be in early youth in a fair way to become a dreamer and a visionary. Perhaps the ease with which Müller could call up subjective ocular phenomena had much to do in directing his attention to the physiology of the senses, especially the eye, which interested him so largely in later life. Accidentally, du Bois heard the lectures on Chemistry by Mitscherlich,

and this seems to have given him a bias to the study of natural science. In 1838 we find him in Bonn, studying chemistry, physics, mathematics, and geology. He took his doctor's degree in medicine in Berlin, and in his graduation thesis, entitled "Quæ apud veteres de piscibus electricis extant argumenta," he embodied the results of some of his researches on animal electricity. He returned to Berlin, where the famous Johannes Müller was Professor not only of Physiology but of Comparative Anatomy and Embryology, the general course of Human Anatomy being given by Schlemm*, under Müller.

In 1840, at the age of 22, du Bois became the assistant of Johannes Müller. After the rather sudden and comparatively early death of the latter, at the age of 57, in 1858, du Bois was appointed his successor in the Chair of Physiology in Berlin, which he held until his death. Such is, in short, the career of du Bois-Reymond.

Now for his work. There are few instances in physiology, or in any other science, where one finds such extraordinary devotion to one chapter as it were of a single subject: a subject no doubt with many ramifications. He tells us in his preface to "Gesammelte Abhandlungen z. Allgem. Muskel-und Nerven-Physik," 1875, that he was twenty-two years of age when Johannes Müller suggested to him to investigate the source of the "Frog-current," of Nobili, and in 1875 he states that after thirty-four years he was still busy in seeking an answer to this question. Indeed he devoted his life to a study of electro-physiology in all its relations, and even to the end electrical currents had a fascinating interest for him.

It is marvellous with what singleness of purpose he devoted himself to the study of electrical phenomena. The physics of muscle and nerve were intensely interesting to him, and this is the more remarkable, as he was a pupil of Johannes Müller, who was a great champion of so-called "vitalismus," as opposed to "mechanismus." Fifty years ago the quartette of German physiologists above mentioned, entirely revolutionised physiology, and applied to its study those methods and principles which are applicable to the study and elucidation of the sister sciences of chemistry and physics. His first work on "Animal Electricity†" was published in 1843.

After dedicating several years to the study of this subject, being incited thereto by Johannes Müller placing in his hands in the spring of 1841 Carlo Matteucci's "Essai sur les Phenomènes Électriques des Animaux," Paris, 1840, he published, in 1841, Vol. I. of his famous treatise, "Untersuchungen über thierische Electricität‡" (dedicated to

* "Johannes Müller, Gedächtnissrede," by R. Virchow. Berlin, 1858.
† Poggendorff's Annalen., Vol. LVIII., 1843. ‡ Berlin, 1848.

Johannes Müller). The first part of Vol. II. (dedicated to Alex. von Humboldt) followed in 1849, and the work was completed in 1860. Even the second edition of Matteucci's work (1844) extends to nearly three hundred pages, but the plates on the Anatomy of the Torpedo, by Paul Savi, are still amongst the best extant. The work is dedicated to Arago and von Humboldt.

C. Matteucci was for a time Professor in the University and Director of Telegraphs in Pisa, and there are some sharp polemical passages in the writings of du Bois as to the views of Matteucci on various electro-physiological matters. Du Bois found a science just in its infancy, and by his own incessant labours he contributed largely to its growth, until it became a mighty subject with a vast literature. He enriched it not only with numerous new facts, but when one thinks of the extraordinary development of the technique of electro-physiology itself, one can form some idea of his labours. Du Bois has enriched the armamentarium of the physiologist by the invention of a great deal of indispensable apparatus. (See his "Description of Some Apparatus and Experiments for Electro-Physiological Purposes.")* We have his un-polarisable electrodes, his modification of the galvanometer of Nobili for physiological purposes, his well-known "Key," familiar to every student of medicine, his compensator for balancing an electrical current, his rheocord, muscle-telegraph, and later, his mercury-key and spring myograph. We have also his famous "inductorium" or induction coil. This was first described by him in 1849, and with slight modifications it is to this day universally used for the generation of induction currents in the laboratory. He had to invent apparatus to meet the ever-increasing problems which his discoveries opened up. In his endeavours to provide apparatus for the investigation and demonstration of electro-physiological phenomena, he was ably assisted by Sauerwald, the famous instrument maker of Berlin.

Any one wishing to read in English a short account of the early discoveries on "Animal Electricity" will find a most readable epitome in the small work entitled "Animal Electricity"†—being an abstract of the discoveries of E. du Bois-Reymond, 1852—edited by his life-long friend H. Bence Jones. It was owing to Bence Jones and Faraday that du Bois had an opportunity of showing his experiments at the Royal Institution, London. He visited Paris in 1850, England in 1852 and 1855, and again in 1866.

We find him writing from London gleefully to his friend G. Magnus under date May, 1855, and recording the fact that he had been able to

* "Beschreibung einiger Vorrichtungen und Versuchsweisen z. Electro-phys. Zwecken." 1861. *Gesam. Abh.*, Vol. I., p. 145 (with three plates).

† London: Churchill, 1852.

show (*i.e.*, to make visible by projection) to a Royal Institution audience his most delicate thermo-electrical experiments, the nerve-current and the negative variation of the muscle-current in the living human body.*

Some of his papers are translated into English. Those on "Secondary Electro-motive Phenomena" and "Electrical Phenomena of Malapterurus and Torpedo" in the Oxford Biological Memoirs.†

His first visit to London was all the more gratifying to him as some of his results had been questioned in the French metropolis, and it was to him always a great pleasure to recount the acts of kindness he received from his English confrères. By an odd coincidence the actual copy of the "Thierische Electricität," once the property of Bence Jones, is now in the Manchester Medical Library. He spoke English with a fluency and grammatical accuracy which was quite remarkable, and indeed he was justly proud of this accomplishment. At his family circle it was no uncommon thing to hear the entire conversation conducted by all members of his family in English.

His great work on "Animal Electricity," published in two volumes, is a monument of literary research on the one hand, and assiduous scientific labour on the other. The historical introduction is charmingly written, and the references to other works in other languages are so numerous as clearly to show the great erudition of its author. It is like reading a tale from the "Arabian Nights," so enchanting and vivid are the descriptions of the early history of this subject given by du Bois. On the publication of the famous researches on animal electricity by Galvani, in 1791, says du Bois: "The storm which was produced among philosophers, physiologists, and physicians can only be compared to that which disturbed at that time the political horizon of Europe. Physiologists believed that at length they should realise their visions of a vital power, physicians began to believe no cure impossible, and it was considered that no one in a trance could in future be buried alive, provided only that he were galvanised." Such has ever been the optimism of human nature, and such it seems likely to remain. We cannot give here an account of the early dispute between Galvani and Volta, nor enter into the controversies between du Bois and Matteucci, but, amongst the incidents of this strange history, it is pleasing to recall the Italian sonnet dedicated to Luigi Galvani on the discovery of galvanism, and in praise of Lucia, the wife of Galvani.‡ Du Bois has translated this sonnet, and perhaps some day, it is to be hoped, some one will be found with sufficient poetic zeal, and sufficiently "gallant," to translate it into English.

* *Gesam. Abhand.*, Vol. I., p. 131.

† "Foreign Biological Memoirs." Edited by J. Burdon-Sanderson. Oxford. 1887

‡ "Thierische Electricität," Berlin Vol. I., p. 39.

Apart from the electrical phenomena manifested by muscle, nerve, glands, and other tissues, and fully set forth in the writings of du Bois, naturally the "electrical fishes" come in for careful study. He edited the work of his assistant, C. Sachs, whom he sent to South Africa to study *Gymnotus.** Sachs died shortly after his return home. While *Gymnotus* had long been known, but few living specimens of Malapterurus of the Nile and Old Calabar reached Europe. Some of the latter came through the medium of a Scottish missionary of Creek Town, Old Calabar, into the hands of Professor John Goodsir, of Edinburgh, and in 1857 Goodsir took one alive to du Bois, while later, in 1859, Mr. Turner, then Demonstrator of Anatomy with Goodsir—now Sir William Turner—carried another specimen alive to Berlin. With these and other specimens du Bois was able to make many important observations. Du Bois was steadily adding new facts to the sum of electro-physiology—his muscle current, nerve current, negative variation of both were all facts—and he adopted an ingenious hypothesis of "electro-motive particles," or "molecules," as he called them, to explain his results, and hence his theory of electro-motivity in living tissues is sometimes called the "molecular theory." He believed and maintained to the end the "pre-existence" of electrical currents in living tissues.

But while du Bois' facts remain, his theory was attacked from a perhaps unexpected quarter. One of his former assistants, L. Hermann,† now Professor of Physiology in Königsberg, published, in 1867, "Metabolism of Muscles," a memoir, wherein he showed that no free O_2 was obtainable from muscle, and many other facts relative to the gases of muscle. This was followed by another contribution on muscle and nerve,‡ which at one blow, as it were, sought to set aside the "pre-existence" or "molecular" theory of muscle currents and nerve currents, advanced by du Bois, and to substitute for it an extremely simple explanation of the phenomena. Hermann published subsequently many papers in *Pflüger's Archiv*, Vols. XV. and XVI., and issued on this subject a collective memoir.§ Hermann came to the conclusion that the "currents" obtained in an injured muscle were not "pre-existent," but were due to injury, and that, in fact, an injured or active tissue becomes negative to an uninjured or resting part, and that uninjured resting muscle is iso-electrical—*i.e.*, it exhibits no currents. Du Bois wrote paper after paper to show that Hermann was wrong, but at the present the views of Hermann "hold the field."

When one contrasts the state of knowledge when du Bois began the study of electro-physiology with what it is to-day, one is amazed at the

* Sach (C.). "Unters. am Zitteraals (*Gymnotus Electricus*)." Leipzig, 1881.

† "Untersuchungen über d. Stoffwechsel der Muskeln." Berlin, 1867.

‡ "Weitere Untersuchungen zur Physiologie der Muskeln und Nerven." Berlin, 1867.

§ "Die Ergebnisse neuerer Untersuchungen a. d. Gebiet. thier. Electricität." Berlin, 1873.

extraordinary development of the subject—a subject so vast as to tax the best energies of one devoting even all his time to its study. Compare the single volume of Matteucci, even in its second edition (Paris, 1844), with the latest work on this subject by W. Biedermann, Professor of Physiology in Jena,* and we may gain some knowledge of the immensity of the subject, and of its extraordinary advancement during the last five decades.

We may recall one of the classical experiments of du Bois, which, when first published, excited enormous interest. He succeeded in demonstrating that currents could be led off externally in man during voluntary contraction, and to him this was a strong proof of the negative variation of the pre-existence muscle current. Consequently it was to du Bois a great source of gratification when A. D. Waller† demonstrated to him, by means of the capillary electrometer, the variations in electrical potential that accompany the movements of the heart in the dog and man—*i.e.*, the so-called "phasic action currents" in an uninjured animal or in man himself.

We need not enter into these controversies here; suffice it that du Bois has left solid contributions to the domain of electro-physiology, and in addition he has invented numerous methods which are applicable to the study of many other physiological phenomena.

His morphological studies were few, being chiefly confined to a study of the arrangements and terminations of the muscular fibres in the muscles he had occasion to use. Perhaps the most interesting of these is his description of the arrangement of the fibres of the gastrocnemius muscle of the frog. In an important paper on "The Acid Reaction of Muscle,"‡ 1859, he showed that the views of chemists that living muscle is normally acid are wrong, and that living muscle is alkaline, and only becomes acid when it has been subject to sustained and repeated contraction, thus demonstrating that physiological activity of muscle is accompanied by chemical change.

Du Bois was more than a physiologist devoted to his "Fach." He was a most accomplished linguist—German, English, French, and Italian were all the same to him as far as reading and speaking them fluently were concerned, but that he used his knowledge of languages to read memoirs in their original dress the copious and accurate notes in his works testify.

Some of his minor pamphlets and addresses are most charming reading, and one is always sure, when a quotation is given or allusion made to any subject of importance, to find a reference—with title and page—to its original source.

* "Electro-Physiologie." 1895. English Translation by Frances A. Welby, 1896.

† *Phil. Trans.*, Vol. CLXXX., 1889, p. 169.

‡ "Ueber Angeblich Saure Reaction d. Muskelfleisches."—*Monatsb. d. Akad.*, Berlin, 1859.

In 1851 du Bois became a member of the Berlin Academy, and in 1867 he was elected its perpetual secretary. In 1858 he was elected successor to Johannes Müller in the Chair of Physiology in Berlin, which he held till his death. Besides his "Animal Electricity," already mentioned, he published his "Gesammelte Abhandlungen"—*i.e.*, his collected papers, in two volumes, 1875—1877, and numerous papers in the Transactions of the Berlin Academy. He was Rector of the University in 1869, when he published his Rectorial address "On the Arrangements in the Universities."

But there is another side to his literary activity, viz., those discourses, sometimes of a semi-popular kind, on scientific subjects, literary and historical characters, which he published from time to time, sometimes addressed to the Academy, sometimes to associations of medical men.

Amongst these may be mentioned "Voltaire in his Relations to Science."* In this short address, in memory of Friedrich II., he gives a most interesting account of Voltaire's studies in physics and mathematics and his dealings with Frederick the Great, and he speaks of that odd conjunction of mortals, Voltaire and Frederick (one the conqueror and statesman, the other the poet and thinker), in the following terms: "Amongst the splendours of the firmament of renown of the eighteenth century two stars stand out among all the rest—Frederick and Voltaire. Together they had one ideal centre of gravity which fixed their conquering path—full, unfettered intellectual liberty and humanity."

His pamphlet "On the German War" (1870) brought him, as well as his friend Mommsen, the famous historian, into sharp conflict with some of his French confrères, and perhaps the bitterness engendered by this controversy of 1870 remained long after. In "The Opinions of Leibnitz and Modern Natural Science" (1871) we have another of his characteristically learned and brilliant orations. "Instruction in Physiology as it was and is" (1878)† is a most interesting paper, as it gives a review of the teaching of physiology during the time du Bois himself was a student. It is the substance of an address given by him on the occasion of the opening of the new physiological laboratories in the Dorotheen Strasse, Berlin, on November 6, 1877. Well may both du Bois and v. Fleischl call the Institute a "Physiological Palace." In it are a dwelling for the professor and his family, rooms without number for various purposes (histological, chemical, and physical), a museum of great dimensions for apparatus, a lecture theatre with a "box" for royalty, but, strangely enough, little accommodation for the student of medicine for learning practical physiology, such

* "Voltaire in seiner Beziehung zur Naturwissenschaft." Berlin, 1868.

† "Der physiolog. Unterricht sonst und jetzt," 1878.

as we understand it in England. Du Bois was singularly proud of his carefully-drawn diagrams, and he tells us that it was in England, in the middle of the fifties, that he learned how valuable these are in teaching—these "mighty aids," as he calls them. Right and left on entering the building are the busts of Albrecht von Haller and Johannes Müller, "the two men who, in their time, gave the greatest impulse to the study of physiology in Germany."

As to the past in physiology, du Bois recalls the fact that as late as 1856, J. Müller lectured in Berlin on "Anthropotomie, comparative and pathological anatomy, physiology, and embryology"! When du Bois was a student there was neither chemical nor what is called physical physiology. The words "tetanise," "muscle curve," and "electrotonus" had not been coined. In 1840 half a dozen experiments—outside those on voice—represented all the objective teaching given under Müller. Probably the first independent Physiological Institute in Europe was that built in Breslau by that keen observer of his own visual field, the discoverer of the germinal vesicle, and, with Valentin, of ciliary motion, the describer of the cells of the cerebellum that bear his name, and the fibres in the heart of some mammals, which also bear his name, to wit, Johannes Evangelista Purkinge, of Breslau, who built an Institute there at his own cost. The first Institute for experimental physiology in Germany was built under Vierordt in Tübingen (1865), and then came that of Ludwig in Leipzig (1869), which has proved at once the type and the parent of all succeeding Institutes throughout the world.

Well may du Bois speak of Physiology as the "Queen of the Natural Sciences," when she is installed so handsomely as in Berlin. In the bye-going he has a gentle tilt at the *Spectator* and *Times*, published in that "classic land of fox-hunting, cock-fighting, and pigeon-shooting," apropos of some strictures passed by them on some arrangements in the new Institute.

Within the space at our disposal, it is hardly possible to refer to all the addresses delivered by du Bois. They have been published in two volumes. Vol. I. contains "Addresses on Literature, Philosophy, and History," and Vol. II. "Biography, Science, and Academical Discourses." As secretary of the Berlin Academy, he was called upon from time to time on various recurring birthdays to pronounce a discourse, in memory of Leibnitz, of Frederick II., of the Emperor William, and others. His intimate acquaintance with French literature led him to deal, not unfrequently, with that brilliant period of French literature, represented by Diderot, Voltaire, and Jean-Jacques Rousseau, with the speculations of La Mettrie and those of the Abbé Galiani. But there are two of his discourses in particular which have attained a wide popularity. The first "Ueber die Grenzen des Naturerkennens" was originally addressed

to the Association of German Physicians and Surgeons at Leipzig, in 1872,* and is one of the most popular of du Bois' addresses, dealing as it does with the limits of natural knowledge. It has passed through seven editions, and has been translated into several languages, including English. "The Seven Riddles of the World"† (1880) is really a sequel to and amplification of the address just mentioned. The views of du Bois on the limits of Natural Science stirred up so much interest—not to say criticism—amongst the laity as well as amongst "philosophers" in general, that the "Seven Riddles" followed as an expansion and explanation of the famous Leipzig address. In this address he prefaces his remarks with a quotation from "Antony and Cleopatra"—

In Nature's book of Secrecy
A little I can read,

and closes it with the word "ignoramibus." He speaks of "Natural Science" as "the conqueror of the world of our day," and seeks for the limits of its sphere of action. He deals with the views of Leibnitz and Laplace. The mystery of matter and energy he regards as insoluble; but, granted certain conditions, he does not regard the first appearance of a living thing upon the globe, or on any other planet, as "supernatural," but only as a distinctly difficult mechanical problem. His next limit is the unfathomable phenomenon of Consciousness. He maintains that the fact of consciousness is not explained by the material conditions on which it depends, but from the very nature of things it can never be so explained. "With the first manifestation of pleasure or pain by an animal organism when first it appeared on the earth, or with the first perception of a quality, there we have the first great gap or gulf which makes the world doubly incomprehensible." Granting what he calls an "astronomical knowledge" of all parts of our organism, even to its minutest details as regards its intimate composition and arrangement, he maintains that the psychical processes themselves would still remain as incomprehensible as they are to us at present. "By no conceivable arrangement or movement of material particles can a bridge, as it were, be formed leading to the Kingdom of Consciousness." Here is the limit of our knowledge, and hence, as regards the mysteries of the material world and the explanation of consciousness on mechanical principles, he is constrained to say "ignoramibus."

Naturally, dicta such as these, coming from one occupying the position of du Bois, excited great attention. Eight years later in his "Seven Riddles" he returns to the subject and replies to his critics. The riddles, or "difficulties," he postulates as seven, and "transcendental" he calls those which appear to him to be insuperable. The first is the question of matter and energy, one limit of natural science,

* "Reden von du Bois-Reymond." Leipzig. † "Die sieben Welträthsel" (1880).

the second is the origin of movement, the third the first manifestation of life, the fourth the apparently purposeful arrangement of natural phenomena, the fifth—corresponding to his other limit—the origin of the simplest sensory impression, the sixth, postulated, however, "not with full conviction," that of thought and its origin, and the nearly related question of the origin of speech, and the seventh and last the question of the "Will."

Du Bois' name will remain embedded in the *Archiv für Anatomie, Physiologie, und Wissensch. Medicin*, carried on by him and Reichert from 1859—77, and previous to that time by J. Müller.

From 1877, a new series began under du Bois, His, and others, and is still continued as *Archiv für Anatomie und Physiologie*, with an anatomical and physiological issue, which appear separately.

Du Bois exercised a powerful influence in scientific circles, not only in Berlin, but throughout Germany. He was a *persona grata* at Court, and was on intimate terms with various members of the royal family. His lectures and addresses were invariably prepared with the greatest care, and the former were always illustrated by a series of beautifully-executed diagrams, while numerous experiments served to impress the facts upon the memory. In later years the work of directing the numerous researches which proceeded from his laboratory on the physical side devolved upon H. Kronecker, professor of physiology in Berne, and latterly upon Gad, professor in Prague, while the histological side was under the direction of Fritsch and Benda, and the chemical department, until lately, was under the direction of Kossel, now professor in Marburg. In the earlier days Hermann (Königsberg) and I. Rosenthal (Erlangen) were his assistants, before they obtained independent professorships.

With Du Bois there has passed away the "doyen" of the older physiologists, and with him one who has long been a conspicuous figure in the scientific world at large.

What Helmholtz, Brücke, Ludwig, and du Bois-Reymond have done for physiology and for practical medicine it would be difficult to compute. All of them lived to a good old age, and were found busy at their work when the last call came. This quartette in Germany, together with Claude Bernard in France, and Donders in Holland, completely changed the whole aspect of physiology, and all afford noble examples of singular devotion to the pursuit of science and the truth for their own sake. When we contrast their long period of activity—all of them exceeded the allotted span of threescore years and ten—with the comparatively sudden break-down of the great teacher of some of them, viz., Johannes Müller, we recall to mind his words, spoken when worn out with work and when recuperation came not—"An der Arbeit klebt Blut."

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